SYNAPTIC MECHANISMS OF RETROACTIVE GENERALIZATION OF EXCITATION FOLLOWING LOCAL TRAUMA TO THE CEREBRAL CORTEX

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UDC 616.831.3-001-092:612.823.5

The authors' previous investigations showed that following local cortical trauma generalized changes take place in the electrical activity of the cortex and of certain subcortial structures [6, 7]. These changes appear as the "EEG desynchronization reaction", i.e., as a change from slow waves of high amplitude to fast waves of low amplitude.

Control experiments showed that the manifestations of generalized EEG activation following trauma to the cortex are due to the corticofugal spread of excitation from the injured area to the generalizing apparatus of the subcortex, followed by the retroactive ascending influence of this generalizing apparatus on the cerebral cortex. For this reason the spread of excitation in this manner becameknown in P. K. Anokhin's laboratory as "retroactive generalization" [1, 6, 9].

The object of the present investigation was to continue the study of the mechanisms of post traumatic activation. It was essential to find out to which cortical synapses the excitation spreading from the injured

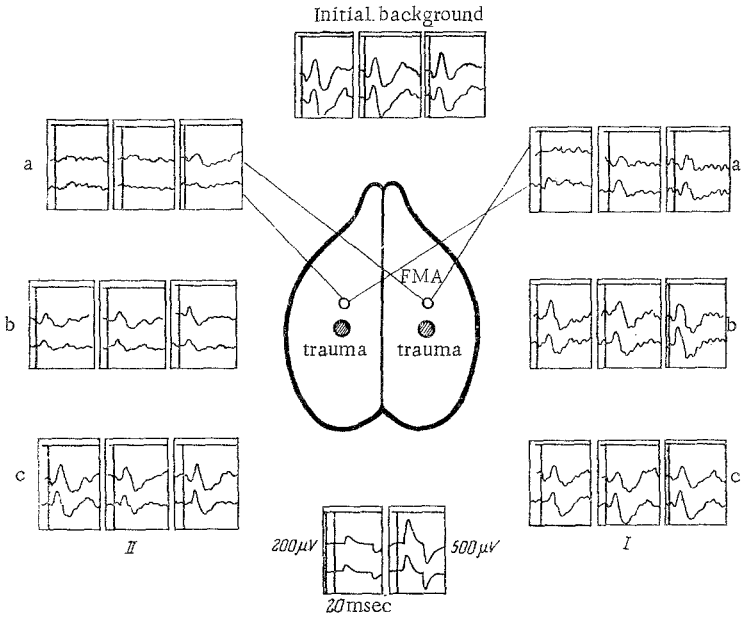

Fig. 1. Effect of local injury to the cortex on configuration of the evoked potential arising in the cortex during application of single stimuli to the sciatic nerve. EEG recorded immediately after the trauma (a), and 2.5 min (b) and 8 min (c) after trauma. I) Trauma applied near the FMA; II) in the opposite hemisphere.

Department of Normal Physiology, I. M. Sechenov First Moscow Medical Institute (Presented by Active Member of the Academy of Medical Sciences of the USSR P. K. Anokhin). Translated from Byulletin' Éksperimental'noi Biologii i Meditsiny, Vol. 64, No. 8, pp. 3-6, August, 1967. Original article submitted May 10, 1966.

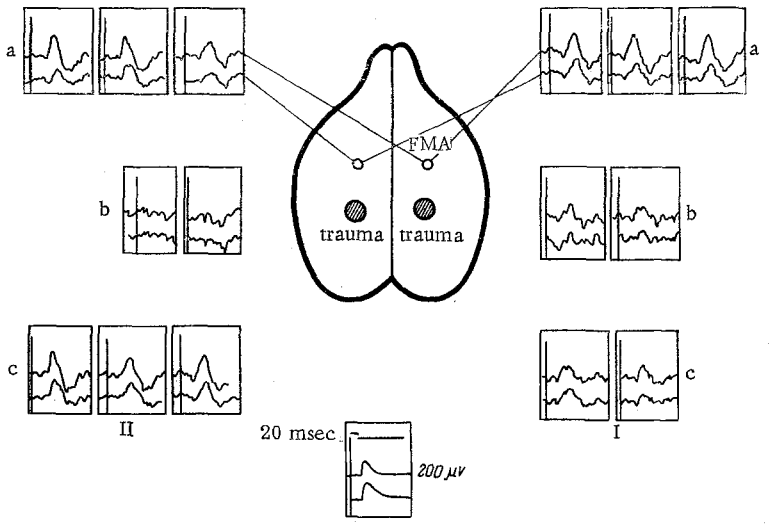

Fig. 2. Changes in configuration of the evoked potential under the influence of post traumatic excitation spreading from the injured area of the cortex after division of the corpus callosum. a) Initial tracings, b) tracings of the EEG immediately after trauma, c) 8 min (I) and 16 min (II) after trauma. I) Trauma applied near the FMA; II) in the opposite hemisphere.

part of the cortex was destined. The indicator of this excitation was the change in the configuration of the evoked potential arising in the specific projection zone of the cortex in response to a single stimulation of the sciatic nerve.

The evoked potential consists of three principal components, each of which is due to excitation of particular synaptic structures in the cortex. The primary positive phase of the evoked potential is associated with excitation of the axosomatic synapses of cortical layers IV-V. The negative phase of the evoked potential is recorded during excitation of the axodendritic synapses of the plexiform layer of the cortex. The secondary positive phase reflects excitation of the synaptic structures of layers II-III of the cortex [2, 3, 8]. Excitation of the cortical synapses during posttraumatic activation must, therefore, be expressed by changes in the corresponding component of the evoked potential.

EXPERIMENTAL METHOD

Acute experiments were carried out on rabbits anesthetized with Nembutal (40-50 mg/kg) or with a mixture of Nembutal and chloralose (15-20 mg/kg). The rabbit's head was fixed in a Horsley–Clark–Dale stereotaxic apparatus. The surface of the cortex was exposed for recording the EEG and for stimulation. The sciatic nerve was dissected out and buried electrodes applied to it. The nerve was stimulated with single pulses of current following at intervals of 10 sec. The electrical responses arising in the cortex were recorded on a cathode-ray oscillograph. One of the recording electrodes was placed in the zone of maximal amplitude of the evoked potential, i.e., in the focus of maximal activity (FMA), the other at the symmetrical point of the opposite hemisphere. In the course of the experiment, local trauma to the cortex was applied by inserting a bundle of fine needles in one operation into the cortical tissues to a depth of 2-3 mm. The traumatic focus was produced either in the ipsilateral hemisphere relative to the FMA or in the parietal region of the contralateral hemisphere. The trauma was repeated 8-10 times in the course of the experiment. Each successive trauma was applied at least 10 min after its predecessor, i.e., after complete recovery of the initial configuration of the evoked potential had taken place. The size of the traumatic focus depended on the diameter of the bundle. Trauma inflicted by one needle was regarded as mild. Strong trauma was applied by a bundle of needles 0.5 cm in diameter.

The evoked potentials were recorded for 2-3 min before trauma, at the moment of trauma, and in the period of development of the reaction and recovery of the evoked potential.

EXPERIMENTAL RESULTS

The evoked potential disappeared completely 1-2 sec after trauma and did not appear even when the strength of stimulation of the sciatic nerve was increased (Fig. 1). Generalized desynchronization was recorded at this time on the cortical EEG.

After 20-30 sec, however, the EEG and the evoked potential both began to recover at the same time. The negative phase of the primary response gradually appeared. Initially it had low amplitude, was more protracted in time, and sometimes was reduplicated. Its final restoration sometimes took several minutes (Fig. 1). The positive phase of the primary response also was restored very slowly. At first it appeared extremely irregularly and eventually returned to normal after several minutes also (Fig. 1). Recovery of the secondary positive phase began later, not until the end of the first minute after trauma, but then it very rapidly regained its initial amplitude. In the recovery period its amplitude sometimes actually exceeded its initial value. Final recovery of the original configuration of the evoked potential coincided in time with final recovery of the original EEG.

The changes described were characteristic of both mild and strong trauma. Naturally in the latter case they developed more rapidly and were more pronounced. Identical changes were observed after trauma of the ipsilateral (relative to the FMA) and contralateral hemisphere.

These experiments show that post traumatic activation is destined for the synapses of different layers of the cortex: in the plexiform layer of the cortex, responsible for the formation of the negative component of the primary response, and to the axosomatic synapses of cortical layers IV-V, excitation of which causes the development of the positive phase of the primary response, and again to the axodendritic synapses, excitation of which is associated with the appearance of the secondary positive potentials [2].

The question arises, to what extent were the changes in the evoked potential described above due to retroactive generalization of the post traumatic excitation? To answer this question, experiments had to be carried out in such a way that the spread of excitation from the injured area along intercortical fibers was completely excluded. Trauma was therefore applied to the hemisphere separated from the FMA by complete division of the commissural fibers of the corpus callosum. However, in these conditions the traumatic excitation also led generally speaking to identical changes in the evoked potential at the FMA as were observed before division of the corpus callosum (Fig. 2).

The results of these experiments show that post traumatic excitation may spread from one hemisphere to the other along closed systems: cortex—subcortical structures—cortex, i.e., by a mechanism of retroactive generalization.

The results obtained, demonstrating that generalization of post traumatic excitation may take place via the subcortical structures do not, of course, rule out the possibility that the spread of excitation may also take place along intracortical fibers in the conditions of the intact brain, as has been demonstrated by other authors [4, 5].

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